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Focusing on human factors while designing a BMI room

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Abstract

The research in Brain Machine Interfaces (BMIs), although in rapid expansion, must still be considered at the experimental level since no widely available BMI system exists for helping people with motor disabilities in everyday life. Transferring BMI applications from laboratories to dedicated clinical services - and later to patient homes - implies, first of all, the specification of perfectly adapted experimental conditions including all the human factors. Our paper surveys various criteria that must be taken into account while designing a room dedicated to BMI experimentation from the ergonomic point of view, as well as adapted experimental protocols. This related work emphasizes the need and the complexity of a global and multidisciplinary approach which places human factors at the centre of the concerns.

Keywords

Assisting system ergonomics, BMI, experimentation room fitting

1. Introduction

BMIs focus on helping disabled people to gain autonomy in daily living. Indeed, they allow direct communication between a man and a computer thanks to the analysis of brain activity. Today, various experimental BMI systems put forward many types of applications (M-H. Bekaert, 2009) to help users overcome a major physical disability by restoring communication (J. Wolpaw, 2002), mobility (F. Galán, 2008), object handling (J. Müller-Putz, 2005), and more recently, to bring new therapeutic solutions (B. H. Dobkin, 2005 and A. Van Langenhove, 2008). However, few clinical studies involving patients with severe neurological disorders have been reported in the literature, and very few consider disabled patients in everyday life situations. Moreover, several studies comparing the effectiveness of BMI approaches on disabled versus

healthy people report conflicting results (L. Kauanen, 2007, and J. Wolpaw, 2004). This implies to perform many more experiments involving physically impaired people to better understand their difficulties and consequently adapt the BMIs.

The BMI research field is usually presented, in the literature, either from a technical point of view or a medical one. Few articles on BMIs deal with the specificities of handicapped people. Very few papers take into account the experimental framework. No one discusses about a way to take into account perturbations during BMI experiments (a bad signal-noise ratio, non standard subject behaviour, and hardware or environment variability) other than removing them. Although some obvious constraints about noise, light sources, accessibility, have usually been considered, no team had regarded this issue as a whole.

This paper surveys crucial criteria while designing a room dedicated to BMI experimentations, as well as adapted experimental protocols. Sections 2 to 5 respectively detail, accessibility, ergonomics of places and tools, layout and experimental protocol definition, without omitting ethical and human aspects. We conclude on the real need of focusing on ergonomic and human aspects all along the BMI design process, in order to make BMIs real palliative technical aids for handicapped people.

2. Accessibility

Real world BMI experimentations have been seldom performed (M. Moore, 2003). More often, such experimentations occurred in clinical environment in a dedicated EEG room or even in the patient's bedroom. BMI research experimentations are essentially performed on able-bodied volunteers. In order to extend such experimentations to disabled people, an environment suitable for both motor-disabled and able-bodied people must be thought.

BMIs as palliative communication tools are dedicated to severely impaired people. As assistive neural rehabilitation technologies, they are specifically dedicated to patients suffering from motor, cognitive or sensory impairments. Accessibility must be considered from a global point of view including different kinds of disabilities such as mobility impairments or gripping disabilities and different profiles of users.

Another important aspect is the legal situation of BMI experimentations. The context of any experimentation performed on human beings by means of biomedical devices must be approved by the appropriate legal department. Many conditions must be checked: the building must be compliant with the standard, a safety cabinet with emergency devices such as oxygen units, or defibrillators must be quickly accessible, and an emergency procedure must be well-defined.

3. Ergonomics of places and tools

According to the International Ergonomics Association, "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among human beings and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance" (IEA 2010).

3.1. Ergonomics in the experimentation place

Taking into account ergonomics in a BMI experimentation room design boils down to consider all the relevant factors implied in working situations such as physical, cognitive, social, organisational or environmental ones. Thus, any working situation can be described by the following items (G. Peninou, 1994):

- Working periods considering their physical fatigue effects but also their duration, accuracy and repetitiveness,
- Resting periods during which energy expense is minimised,
- Complex or simple gestures defined according to their efficiency,
- Working postures including attitudes and positions,
- Mental workload in terms of intellectual and/or emotional constraints and intellectual fatigue,
- Workplace ambience that can spark off an early fatigue.

Studies have shown that the design and ambience of working spaces affect user comfort, motivation, stress tolerance and well-being. These factors impact on error and accident rates, productivity and work quality.

3.2. Ergonomics in equipment and technical tools

Human-machine interface (HMI) ergonomics consists in adapting technology to individuals and not the reverse. For a real use of a final product, few constraints must be imposed to the user or to his environment. The final product must be thought, as any HMI, according to the Bastien and Scapin's criteria (J.M.C. Bastien, 1992) that are essential ergonomic criteria established by academic research. Generally speaking, user's acceptance is the most important criterion as far as the tools are on purpose and easy to use. An assistive system is adopted earlier by the user when it fills his expectations as well as his own fashion, design and aesthetic criteria. Any assistive technique provided to a disabled person requires his psychological acceptance (R. Khomiakoff, 2009) and BMI systems have still to evolve with respect to all of these aspects.

4. Experimentation room space layout

Organising a BMI experimentation room consists in designing the different spaces dedicated to all the participants and their communication, but also dealing with the space fitting and the workplace ambience.

4.1. Design of the different spaces

In accordance with the literature, it seems appropriate to split the experimentation room into two distinct well-identified spaces, both adapted to the specific needs of the protagonists: one observation space dedicated to the experimenters to control the whole experiment, and one experimentation space dedicated to the subject.

On the subject side, a manoeuvring clearance space must be allocated so as a workspace for him to perform the experiment required tasks. On the experimenter side, an ergonomic workplace for the experimenter, a smaller place for the subject, a waiting space for the third potential party, and a clearance space must be allocated.

4.2. Space layout

Space layout must be optimised, secured, adapted to every one and identically repeatable from session to session. To properly place the furnitures and the BMI equipments, it is important to notably worry about workspace brightness, desk orientation, circulation and communication of the different protagonists. All the elements need to be set through the spaces depending on their bulk, use and load frequency such as to reduce awkward postures and moving constraints, and to extend time-saving.

On another hand, the space layout must be defined to ensure reliable, discernable and adapted feedbacks.

4.3. Participants circulation and communication

Two kinds of circulation areas can be considered: frequently passing spaces and critical areas where several persons can possibly meet at the same time. Clear widths of each space must be large enough for disabled people movements. Conforming to anthropometric data ensures enough space for able-bodied as well as for disabled people to move freely and safely. It is also important to organise space while thinking about direct people communication without disturbing experiment sessions.

4.4. Spaces ambience

In order to be able to measure the influence of the environmental perturbations intentionally generated by the experimenter, it is better to experiment BMIs within a perfectly controlled ambience with respect to thermal, lighting and sound constraints.

Electromagnetic environment must also be controlled to ensure effective EEG recording measurements. It is better to perform the BMI using battery powered EEG recorders, to turn off mobile phones and to avoid neon tubes switching during signal recordings.

4.5. Subject well-being concern

To limit stress factors during BMI experiment sessions, it is important to give priority to the subject well-being and to make his disability adaptation process easier as well as his assistive technology acceptance.

The experimenter can highly contribute to make the subject feel secure. Indeed, if the experimenter totally masters both room spaces and BMI system, he is able to manage the experiments without any mental overload. Therefore, he has much more the opportunity to focus on the human aspect (discussing, reassuring, protection behaving, inducing a mutual confidence feeling). It is the reason why, at the prime time subject and experimenter meet, the experimenter needs to quickly overview the subject profile.

5. Experimental protocols definition

A protocol must be defined by the scientist for any experimentation according to the performed study and to the expected results. It guarantees the experiment reproducibility and then the comparison of the results. Thus, such a protocol must be written, validated and followed by all the participants. Some guidelines can be outlined so that next protocols meet efficiency requirements as well as reproductibility, comfort and well-being ones.

5.1. The experiment planning

As soon as a disabled person is involved, an experiment planning meeting must take place well before the experimentation itself, to ascertain the experimentation feasibility, to reduce the experiment duration and to avoid any subject disappointment.

During this meeting, the experimentation steps are described, the background is specified, and major instructions are given using information transmission channels specifically adapted to

the subject understanding capabilities. The patient's interview may also highlight some medical criteria inducing his exclusion from the experimentation.

5.2. Protective measures

It is recommended for the experimenter to come on the experimentation day with a checklist of the essential guidelines to communicate to the subject prior to the experiment. Indeed, the experimenter must check that the patient well understood everything. He must also inform the patient that he may stop the experiment whenever he wants. A consent form must absolutely be signed before starting the experiment.

5.3. Time management

To properly manage both patient and experimenter timing, each phase duration must be defined according to its importance. An experiment can be composed of six successive phases.

- ***The welcome phase***, relatively short, can be seen as a moment of courtesy.
- A relatively extendable time must be devoted to ***the presentation phase*** according to the stress tolerance and the understanding capabilities of the subject.
- ***The preparation phase*** is essential for the experimenter and requires him a particular attention setting up all the equipment. The subject is not directly involved in this phase.
- ***The recording phase***, the core of the experiment, can start with a training session. This guided and coercive phase requires a maximum of relaxation and concentration.
- ***The disassembly phase*** has no influence on the experiment efficiency.
- ***The report interview phase*** yields an experience background from the experimenter to the subject. This communication time is essential.
- ***The conclusion phase***, very short, closes the session. It is more a courtesy period to thank the subject's involvement.

5.4. People management

People management factors such as consistency, respect, inclusion, trust and honesty have a decisive influence on the experimentation sessions. Therefore, the sessions must be adapted to the needs and the difficulties of the subject regarding these factors which implies consideration to the subject and respect of the differences.

6. Conclusion

This paper shows that human factors need to be the major concerns while optimising the general performance level of the BMIs as assistive systems. In the literature, many authors relate the crucial need of developing BMIs while taking into account adaptability, autonomy, training methods, environment artefact control, functionality, and aesthetics. Thus, the challenge is to follow a global approach aiming at the BMIs adaptation to the real user needs early in the design. Futures BMIs will really need to be assessed as functional and adaptable systems even if it is difficult to adjust the systems for everyone.

Testing the different BMI systems already developed in the research laboratories would really help identify the applications transferable to the patient's home with respect to his real needs. This implies not only more experiment sessions with handicapped people, but also more assessments, more reviews and more feeling collection.

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